HUMAN FACTORS OF
Automation In The Airline Cockpit

INCREMENTAL AUTOMATION IN THE COCKPIT

We incrementally automated aspects of the flying job:

Billings, C. E. (1991). Human-centered aircraft automation: A concept and guidelines. NASA Tech Memo.

1. Hands and feet off the controls: AUTOPILOTS (1914) and AUTOTHROTTLES (1945)

2. Pursue target courses, altitudes, and speeds: FLIGHT DIRECTOR (1950s)

3. Series of targets that comprise an entire route: FLIGHT MANAGEMENT COMPUTER (1983)

4. Detect and deal with abnormals: ELECTRONIC CENTRALIZED AIRCRAFT MONITOR (1983)

Our practice is to use automation during most phases of flight. We assume that pilots will **monitor** the automation to **maintain awareness** and **understanding** of what it's doing, and **be ready to intervene** when the automation misbehaves or is overwhelmed.

MONITORING TO MAINTAIN AWARENESS

The hardest and most persistant problem we face. Reasons:

DEPLETION

Sustained vigilance (monitoring) is known to be arduous and depleting.

OTHER COCKPIT TASKS

Pilots avoid long periods of "sit and stare" as they perform other cockpit tasks. But these also result in monitoring lapses (Loukopoulos and Dismukes, 2001).

TASK-UNRELATED CONVERSATION AND THOUGHT

Pilots quickly turn to task-unrelated conversation
"Sterile cockpit rule" in 1981 (Wiener, 1985)
When not talking about it, they're thinking about it (Casner and Schooler, 2014)
Craig (1978): Do pilots adjust their attention-paying to match perceived need?

Many demonstrations of lowered awareness (Endsley and Kiris, 1995; Casner, 2005).

Status: Lots of attention drawn to this problem but no solutions. We currently use a "catch as catch can" approach to monitoring. We do little to train monitoring. The idea of designing a more interactive conversation between pilot and automation (Hutchins, 1990), or using less automation to maintain target levels of workload (Bainbridge, 1983) have never been explored.

UNDERSTANDING WHAT THE AUTOMATION IS DOING

Even when pilots actively monitor, understanding what's going on is far from guaranteed

Cockpit automation is a complex collection of moded sub-systems that interact with each other in sometimes surprising ways:

Sarter, Woods, and Billings (1997). Automation surprises. *Handbook of Human Factors and Ergonomics*.

Wiener's Three Questions (Wiener, 1989)

Why did it do that? *What's it doing now?* *What will it do next?*

Status: "Shared understanding" is known to be effective (Norman, 2007) but we don't teach conceptual models of how automation works or pursue human-centered cockpit designs despite some promising proposals (Hutchins, 1996; Feary et al., 1998). Instead, industry is moving even more toward the use of pre-written procedures and slimming ground school syllabi. Meanwhile, automation is becoming more complex.

BEING READY TO INTERVENE

Situations that require pilot intervention are often unexpected and sometimes unique. Accidents continue to result from failures in these situations. Reasons:

LACK OF MONITORING AND/OR UNDERSTANDING

The flight crew has lost awareness and fails to make sense of the situation before it is too late (e.g., Asiana 214).

ATROPHIED SKILLS

Hand-eye skills stick even when not regularly practiced, if once well-learned.
Cognitive skills (recalling procedures and reasoning steps) need regular practice.

Casner, Geven, Recker, and Schooler (in press). The retention of manual flying skills in the automated cockpit. *Human Factors*.

GENERALIZABLE SKILLS NEVER REALLY ACQUIRED

Airlines practice intervention during abnormal events using a single example of each.

Casner, Geven, and Williams (2013). The effectiveness of airline pilot training for abnormal events. *Human Factors* 55(3), 477-485.

If we rely on humans to deal with abnormals, the training requirements are heavy.

AUTOMATION ASSISTANCE DURING INTERVENTIONS

Automated Systems That Take Over

A few early and painful examples of automation overriding pilot actions and leading to an accident. But does the automation perform better than the crew (yet)?

Automated Systems That Tell Pilots What To Do

We have many simple examples of this now: TRAFFIC COLLISION AVOIDANCE SYSTEM, GROUND PROXIMITY WARNING SYSTEM. Procedure: "Don't think, just do."

Historical efforts to offer advice under more sophisticated circumstances:

Banks, S. B., Lizza, C. S. (1991). The Pilot's Associate: A cooperative, knowledge-based system application. *IEEE Intelligent Systems and Their Applications* 6(3), 18-29.

Automated Systems That Leave The Pilot In Command

The use of "informative" displays that provide information to the crew. Many accidents in which the flight crew, left in charge, did the wrong thing.

THEN WHAT MAKES FLYING SO SAFE?
(How Much of This Is True For Driving?)

WE MINIMIZE ERRORS

Pilots Are Hand-Selected (and we pick "carbon copies")

Pilots Get Lots of Training (initial and recurrent)

Pilots' Observable Actions Are Highly Policed

Standard Operating Procedures (SOP)

We Learn A Lot From Our Accidents and Incidents

WE TOLERATE ERRORS

Many Redundancies

Reliable automation is handling much of the flying

Two pilots in the vehicle, alerts and alarms

Air traffic control, FAA, pilot culture

Big Sky, Little Planes

Wide tolerances, time to think and react, LUCK.

AIR TRAFFIC CONTROL

Master plan

Little airplane autonomy

Palmer, Hutchins, Ritter, and van Cleemput (1991). Altitude deviations: Breakdowns of an error-tolerant system. NASA Tech Memo.

Degani, Chappell, and Hayes (1991). Who or what saved the day: A comparison of traditional and glass cockpits.

IMPRESSIONS ABOUT AUTOMATED CARS

Maintaining Awareness

Driver inattention in an entirely manual car is bad now. Task-unrelated activity (e.g., phones) and thought running wild:

Yanko and Spalek (2014). Driving with the wandering mind: The effect that mind-wandering has on driving performance. *Human Factors* 56(2), 260-269.

He, Becic, Lee, and McCarley (2011). Mind wandering behind the wheel: Performance and oculomotor correlates. *Human Factors* 53(1), 13-21.

Galera et al. (2012). Mind wandering and driving: responsibility case-control study. *British Medical Journal* 345.

Drivers seem to welcome new distractions. Talking, stereos, phones, smartphones, wearables.

Attentive drivers of semi-automated cars … ?

Who *wants* to drive? (safety concerns about automated cars aside)

IMPRESSIONS ABOUT AUTOMATED CARS

Understanding the Automation

We don't have this problem much in cars (yet).

Possible with a conceptual model of the automation that is taught and shared between car and driver.

But might require a tear-down of what we have now.

Being Ready To Intervene

No opportunity to select drivers; little opportunity to train them.

Requires success in above two areas (awareness and understanding).

My Impression: Full automation, hard takeover approach